CEMENT
AND
CEMENT MANUFACTURE
INCORPORATING "PORTLAND CEMENT"

Price 1s. Monthly. Annual Subscription 12s.

PUBLISHED BY CONCRETE PUBLICATIONS, LIMITED,
20, DARTMOUTH STREET, WESTMINSTER, LONDON, S.W.1.

PUBLISHED 20TH OF EACH MONTH.

VOL. 2. NO. 2. FEBRUARY, 1929.

Cement Grinding.

In the early days of the manufacture of Portland cement the finished product was very coarse compared with that of to-day. The clinker was produced in either chamber, bottle, or shaft type kilns; crushing and grinding were effected in combinations of jaw-crushers and mill-stones, or jaw-crushers, roll-crushers and mill-stones; classification by sieving was applied to the finished product. The limiting residue was frequently given as 5 per cent. on the 50-mesh sieve, and later on the 100-mesh sieve. It was a recognised practice to "dress" or "run" the mill-stones to produce the desired residue or fineness of the product. Although this limiting residue now appears high, as finish-grinding was effected by mill-stones it is probable that the percentage of flour was high and this flour no doubt contributed largely to the cementitious value of the cement. Unfortunately no records exist of the flour content of this early material.

The earliest mechanical grinding mills made their appearance in the form of edge-runner mills, Askham pulverisers, Collis mills, Bradley pulverisers, etc.; the product of these single-mill units was also classified by sieving. The pebble-charged tubemill was introduced in England about 1888 or 1889 as a finish-grinding unit, and the adaptation and use of this type of mill provided improved facilities for finer grinding. The use of these mechanical mills as preliminary units, with the tubemill as the finishing unit, became quite common practice.

Arising out of early experience with the tubemill, the ball-mill came into service as a preliminary mill also. Its product, however, appeared to have different characteristics; it was gritty and appeared to contain less fines than the product from the other preliminary mills. Sieving elements were incorporated in or followed the operation of all these preliminary units, and no sieving of the tubemill product was necessary.

Some fourteen or sixteen years ago a demand for a more finely-ground product was created, and to meet this demand " metal " grinding bodies of small size were used in the finishing mill. These small and heavier bodies fulfilled the desired object, but, owing to their greater weight, greater power became necessary and a greater amount of heat was evolved in the process; this evolution of heat resulted in a considerable increase in the temperature of the mill, the grinding bodies, and the cement. The temperature rise in some instances reached a high figure and was the cause of much trouble with the mill lining, grinding bodies, and the cement itself. The cement adhered to the lining and materially reduced the size of and muffled the mill; it coated the media and reduced the grinding effect; while the setting-time of the cement became unstable and out of control.

Various attempts were made to remedy these difficulties. In one instance a compressed-air water ejector was used for spraying finely-atomised water in the mill; this secured a reduction of temperature, but the general results did not prove commensurate with the power expended. The greater part of the difficulties was ultimately overcome by spraying cold water on the outside of the shell of the mill. This method materially reduced the temperature and cured most of the difficulties, but it caused rapid deterioration of the steel shells and produced a dirty and sloppy mill-house.

In cement grinding, as with many other processes, there has been a growing demand in recent years for larger units and larger groups of units. With regard to larger preliminary mills, the type in use did not appear to lend itself to any considerable increase in dimensions, and no finishing mill then in use could be considered large. The largest preliminary mill in use fifteen years ago could only absorb 100 to 120 B.H.P., and the largest finishing mill 150 to 175 B.H.P. When a number of units of even this size have to be accommodated in the same mill-house, the building becomes large and the floor space considerable. Moreover, the type of units then existing required different levels for installation, and this in turn made the duty arduous for the attendant. This latter objection, of course, might be met by installing elevators, and possibly conveyors, between the preliminary and finishing mills. This, however, would considerably increase the floor area and the cost of installation.

Subsequently a single-mill unit or compound mill was evolved which avoided the inherent difficulties and objections met with in the installation of the double-mill unit. These single-mill units could be constructed mechanically sound, but the tuning-up for efficient operation proved troublesome and the temperature difficulties referred to earlier were again encountered. Finally a good connection was established between the length of the separate chambers and the size of the grinding media; and to-day these single-mill units are operating as efficiently as the double-mill units.

It has since proved possible to design mills suitable for any tonnage and to absorb any reasonable power. A single-mill unit (300 H.P., 8 to 10 tons per hour) can be designed and its performance accurately foreshadowed. A large similar unit (1,200 H.P., 32 to 40 tons per hour) can also be calculated with the same confidence and in exactly the same way.

A natural question in the light of later experience is, " What advantages or disadvantages has the double-mill unit installation compared with the single-mill unit installation? " To answer this question, the duty and operating conditions must be considered. The essential duty is obviously to reduce hard burnt clinker from $\frac{3}{4}$ in. to $\frac{3}{8}$ in. diameter until, say, 95 per cent. will pass a 180 or 200-mesh sieve. This duty represents a considerable amount of mechanical work, and mechanical work may be of two kinds, namely, useful work and useless work. Useful work is that in which crushing and grinding are effected without any increase of temperature; useless work in crushing and grinding is represented by any considerable increase of temperature.

As crushing and grinding cannot be effected at 100 per cent. efficiency some increase of temperature will naturally result, but it is desired to keep the temperature increase as low as possible. Temperature rise is most pronounced when metallic grinding media impound upon similar media. It is least when metallic grinding media impound upon a good bed of clinker, grit, or cement. Temperature rise is also serious when the grinding medium at any stage in the process is too large for its duty. Two things thus appear especially necessary: (1) suitability of size of the grinding media, and (2) a reasonably good bed of cement.

Experience seems to indicate that both these conditions are more easily obtainable in a double-mill unit than in a single-mill unit. It is possible, however, to obtain the conditions in any mill if care is taken in the arrangement and speed of the mill and the selection of the grinding media.

Ventilation must also be referred to: not the ventilation that consists exclusively of air movement, but as the means of carrying away the moisture released in the grinding process. It will be admitted at once that ventilation can be more naturally obtained in the double-mill unit than in the single-mill unit, the " open " arrangement of the preliminary mill and the fitting of sieves both facilitate this. A small amount of cooling is also effected in the grit passing from the preliminary mill to the finishing mill.

In reviewing the two types of unit generally, and taking the oldest established first, it may be said that the apparent advantages of a double-mill installation are:

(1) More positive sizing of the grinding media in both units.
(2) Improved facilities for ventilation and cooling.
(3) Quicker change-over from one residue to another.
(4) Less risk of a " nibby " product.

The disadvantages appear to be:

(1) Large floor space and higher capital cost.
(2) Large number of auxiliaries.
(3) Increased attention and higher operative cost.
(4) Increased number of mills for the same output.

Taking the points in sequence, the following comments are offered in the light of recent experience with large single-mill units:—

(1) The difficulty in sizing the grinding media is more apparent than real. The subdivision of a single-mill unit and the selection of the grinding media can

be effected as satisfactorily as that of the double-mill unit, and grinding can be carried out for nearly the same B.H.P. per ton.

(2) Recent experience indicates that large single-mill units can be ventilated as efficiently as the double-mill units; it, however, still appears necessary to use a water-spray for cooling the shells.

(3) and (4). These advantages are only apparent. If all large single-mill units were fitted with apparatus for weighing and delivering a regular feed there is reason for assuming that the single-mill residue could be controlled as definitely as that from a sieve-fitted preliminary. As large mills are not fitted with this feed-weighing device, excess grinding is invariably carried out to avoid a " nibby residue."

All the disadvantages mentioned are admitted.

It may therefore be said definitely that it is possible to construct and load a single-mill unit of any size with grinding media that will be exactly suitable for any size of feed and product. The arrangement of this type of unit is the simplest possible. There appears to be no limit to size or capacity. The clinker need only be fed to it and the ground cement conveyed away. There need be no auxiliaries of any kind; it can be self-contained and complete for its duty.

Brief consideration may also be given to the possible performance of the pear-shaped air-swept single-mill unit. Only a very few of these mills are in operation in this country, and it is difficult to obtain exact data of their performance. Most of the mills in service are operated in conjunction with a classifier unit. Excessive classification is practised, and the amount of feed is several times as great as the amount of the finished product. The principal claim made for this type of mill is that the material is passed to the warehouse as soon as the particles have reached the desired size. It thus appears that the mean particle size will approach the maximum size, and the amount of " fines " and " flour " will be small. With particles of very small dimension the air velocity must be kept very low, and classification by air on a large scale will possibly prove a troublesome process; the finer the product the more difficult will be the operation of classification. As a matter of fact, air classification may not prove an economic proposition at all for a very fine product.

During the last year or two the value of " flour " as the cementitious element in the cement has been realised, and leading manufacturers are already adjusting their processes to secure a high percentage of this element. It is admitted that as yet there is no standard definition of flour, neither is any reference made to it in the British Standard Specification (No. 12, 1925). Classification in this specification is determined entirely by the percentage of fines and residues.

Accepting the fact that the cementitious value of Portland cement is determined by the percentage of flour, one would naturally ask which type of mill delivers the largest percentage of flour most consistently. From the previous consideration of the air-swept mill it would appear that this type of machine should be ruled out first if it is agreed that the mean particle-size approaches the maximum limiting size and, owing to this, the small amount of " fines " and " flour."

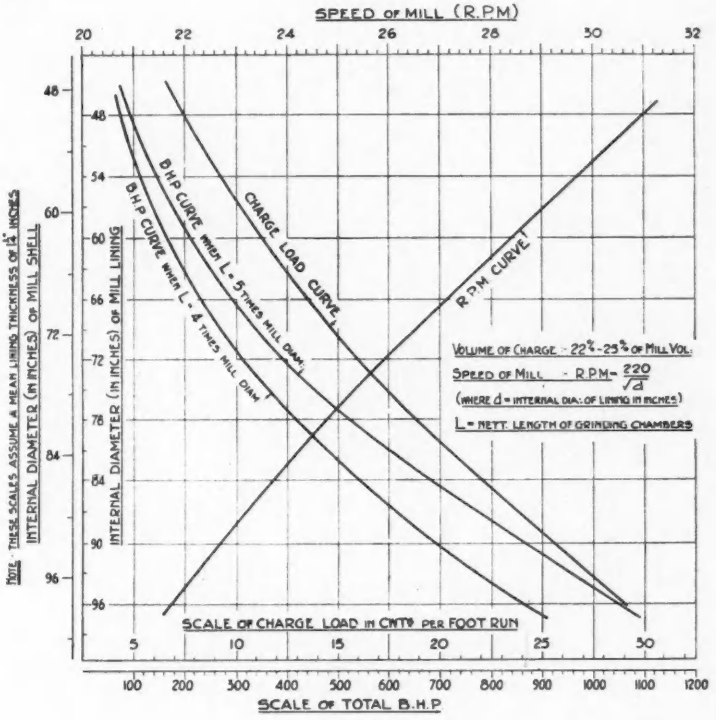


Fig. 1.

With regard to the characteristics of the products from the double-mill unit and the single-mill unit, as there is less risk of " nibs " in the product from the former, owing to the particles being passed out of the preliminary mill as soon as the residue condition has been reached, the mean particle-size from the double-unit mill will approach the maximum size and the flour content will probably be low. In the case of the single-mill unit, as the whole of the material is subjected to the grinding process during the whole of the time it may be reasonably assumed that the mean particle-size will be lower and the flour content higher. It is assumed that the relative speed of the mill, the size of the grinding media in the finishing chamber, and the upper limiting residue are the same in both cases.

In considering the whole of the factors involved, it is not unlikely that for small mills, small plants, and small outputs the double-mill unit correctly tuned up will prove the most satisfactory proposition. In the case, however, of large plants and large outputs, the single-mill unit appears to be the correct type of plant to instal; careful tuning-up, however, will be necessary exactly to suit the operating conditions.

As the single-mill unit loaded throughout with metallic grinding media is becoming more generally adopted for new and large plants, a graph (Fig. 1) giving essential data in connection with it has been drawn especially for this article. In examining the graph and bearing in mind the general conditions under which these mills operate, it will be appreciated that considerable latitude in dimensions, load, speed, and power is possible.

The Cement Industry in Corea.

H.M. Consul General at Seoul makes the following interesting report :—

" The building of irrigation works, hydro-electric works, railways and harbours and civil engineering generally have created a steadily increasing demand for cement in Corea. In 1927 there was an import from Japan of 84,000 tons valued at Yen 2,904,000, but about double this amount was produced in Corea itself.

" There is at present only one cement works in Corea—that at Shokori, a few miles out of Heijo. The works belongs to the well-known Onoda Cement Company of Japan, and has a total capacity of 3,500,000 bags (of 50 kilogrammes).

" This company is now erecting other branch works at Sennairi, a few miles north of Censan on the east coast, which is to have a capacity of two million bags. This works is to be ready for operation early in 1929.

" The total output of the two works will be approximately equal to the Corean demand, and as a monopoly of the market is said to be impracticable, an outlet for some 100,000 tons will have to be found if the works are to be operated to capacity.

" Each of these works has an unlimited supply of limestone and clay at its doors. There is also coal in close proximity, but, as it is not entirely suitable, it is necessary to import from Fushun or Japan a portion of the fuel consumed in burning the cement. The gypsum added to the lime and clay is imported.

" The method used is the rotatory process, as in Japan. At both works the tube-mills were made in Japan, as also the steel balls used in grinding. The steam turbines used for power are Swiss and the generators German; British makers were represented in the boilers and also in a small stationary oil engine.

" It is said that the Skokori cement has already earned a high reputation and has been exported to Tokyo for use in reconstruction work. The new works at Sennairi have been laid out with an eye to future extensions, and considerable space has been left for the purpose."

Franco-German Negotiations.

We understand that negotiations are in progress between France and Germany with a view to an agreement similar to that now existing between France and Belgium (a control of exports into each other's home markets).

Portland Cement and Pozzolanas.

(CONTRIBUTED.)

THE question of pozzolanic cements was briefly touched on by Mr. A. C. Davis in his interesting article dealing with the " Raw Materials for Portland Cement Manufacture " which appeared in the January issue of " Cement and Cement Manufacture." Pozzolanic cements are, as Mr. Davis points out, well known historically since there still exists evidence of their successful use by the Romans, and even now similar cements are produced on the Continent from mixtures of slaked lime and granulated blast-furnace slag or other pozzolanas. While such cements are very naturally not considered by the architect and engineer to be equal to modern Portland cements, there is a growing tendency—particularly on the Continent—to investigate the effect of a small addition of some pozzolanic material to a true Portland cement with a view to neutralising the lime set free during the setting reactions.

Assisted by better mixing, grinding, and burning machinery, by more efficient chemical control, and spurred on by the advent of aluminous cements, the manufacture of Portland cement has recently undergone many refinements, resulting in a great improvement in quality, particularly insofar as its rapid-hardening properties are concerned. The two factors playing an important part in this improvement are a higher proportion of lime and very much finer grinding, both of which, however, tend to increase the proportion of " free lime " disseminated throughout the resultant concrete.

Under normal conditions this " free lime " has no deleterious effect, but in the event of attack by fire it may cause disintegration sufficient to bring about the failure of the whole structure, while it is readily attacked by sea-water, sewage, and other destructive agents. In the case of fire the cause of failure is the dissociation of calcium hydroxide at temperatures exceeding 400 deg. C. causing contraction followed by expansion on the subsequent rehydration of the lime by the moisture in the atmosphere.*

Attempts have therefore been made to utilise various pozzolanas, both natural and artificial,† with their known property of readily combining with hydrated lime at ordinary temperatures and in the presence of moisture to form stable insoluble compounds, as a means of neutralising this element in Portland cement. Most of this work has been initiated on the Continent, particularly in Germany and Denmark, but in this country Scotland has for some years been producing a Portland cement containing a small pozzolanic addition in the form of granulated slag.

The ultimate aim of the modern cement manufacturer is to produce a material having the hardness of granite within 24 hours of mixing, and capable of with-

*This point is dealt with in detail in the Building Research Board's Pamphlet on " Fire-Resistant Construction " (Special Report No. 8).

†Full details of both artificial and natural pozzolanas together with the location and extent of the principal deposits of the latter are given in the Building Research Board's Pamphlet on " Pozzolanas " (Bulletin No. 2).

standing attack by fire and other destructive agents. The rapid-hardening Portland cements produced to-day indicate that the first ideal is not outside the bounds of possibility, while the results obtained by a pozzolanic addition of granulated slag appear to indicate that a suitable addition of one or other of the various pozzolanas will be the means of obtaining the second ideal and lead to the production of a Portland cement having not only rapid-hardening properties, but also powers of resistance to special conditions equal to those possessed by aluminous cements.

New Masonic Lodge.

THE Lodge of Permanence No. 5044, which has been formed primarily for those intimately connected with the Portland cement industry, was recently consecrated at the "Cafe Royal" by V. W. Bro. Sir P. Colville Smith, C.V.O., Grand Secretary, assisted by R. W. Bro. Lord Fairfax of Cameron, P.G.W., W. Bro. Major The Hon. Edward Lascelles, D.S.O., P.G.D.; V. W. Bro. Revd. Canon F. J. C. Gillmor, M.A., Past Grand Chaplain; V. W. Bro. C. R. I. Nicholl, G.D.C.; W. Bro. W. E. Menday, P.A.G.D.C.

W. Bro. Reuben Thain was installed as the first W.M., and R. W. Bro. The Right Hon. Lord Meston, P.G.W., acted as I.P.M. Representatives of most of the important Portland cement companies have already become members, and the success of the Lodge appears to be assured.

Cement Production in Finland.

MESSRS. LOJO KALKVERK AKTIEBOLAG, of Gerknäs, Finland, write as follows:—"On page 35 of the January number of 'Cement and Cement Manufacture' you state that 'The two Finnish factories Pargas and Lojo are to increase their capacity from 650,000 to 1,100,000 casks per annum.' We beg to draw your attention to the fact that the Pargas Kalkbergs Aktiebolag in 1928 produced 1,150,000 casks and the Lojo Kalkverk Aktiebolag 425,000 casks. The increase mentioned by you probably refers to the enlargements carried out at our factory. Our new 105-metres long Smidth kiln was started up at the beginning of March and our capacity brought up to 650,000 barrels, but the new plant being installed is sufficient to enable us to increase the capacity to 1,100,000 barrels."

Cement Manufacture in Dalmatia and Jugo-Slavia.

A CORRESPONDENT in Genova sends us an interesting note on the cement production in Dalmatia and Jugo-Slavia, in which he says:—"Artificial Portland cement is being manufactured only at the inland cement factories in Jugo-Slavia, such as Beočin, Slovenia, and others, but all the factories situated in Dalmatia factory installed two new rotary kilns, but the cement produced in these kilns is natural Portland cement, as the marl is fed into the kilns roughly ground only and without any previous fine grinding or mixture."

Tests for Fineness of Portland Cement.

By S. DICKSON, F.C.S.

THE British Standard Specification for Portland Cement states that the residue on a sieve $180 \times 180 = 32,400$ meshes per sq. in. shall not exceed 10 per cent. The great improvement in the grinding of Portland cement since the last revision of the Specification necessitates another method of determination of the coarse residue, as most cements leave very little residue on the 180 sieve, and to use a finer mesh is neither practicable or desirable.

Flourometers have been in use for many years and have proved of definite use, but they have never been accepted as standard instruments for testing the

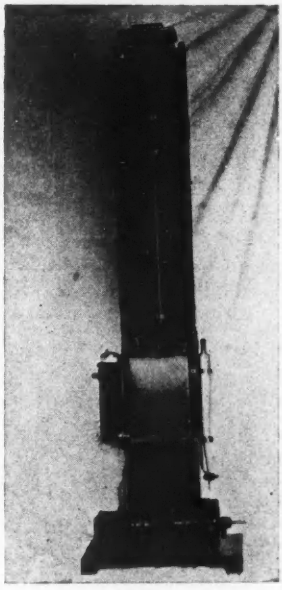


Fig. 1.

fineness of cement. Now that much cement is of rapid-hardening quality it becomes more and more important to ascertain with certainty the amount of inactive core or coarse residue.

The property of modern Portland cement to harden rapidly is due solely to the speed of the chemical reaction between the cement and the water with which it is gauged. To obtain a high speed reaction it is necessary, *inter alia*, for the cement to contain a large proportion of very small particles, and it is the aim of cement manufacturers so to grind their product that a large proportion of the cement shall be of such particle size that a high reaction speed is possible.

There seems some reason to believe that particle size is one of the governing factors in relation to the strength of the cement, as, although the chemical composition may vary through fairly wide limits, yet with two chemically different cements having the same particle size the strength does not vary appreciably. There is, therefore, every reason to determine with accuracy the proportions of particles of small size which are commonly termed " flour " and the coarser ones which may be termed " core." Flourometers now on the market give results which have proved useful, but there is still room for a more exact method for estimating the proportions of flour and core.

Elutriation, as distinct from air separation, has proved successful in the separation of the coarser particles in Portland cement, for when a suitable liquid is used the coarse particles are gently washed free from the adhering flour and can then be collected and weighed and measured if necessary. Elutriation may also be used in the same manner as a series of sieves, for by varying the speed of flow the coarse particles will be graded in accordance with the particular speed

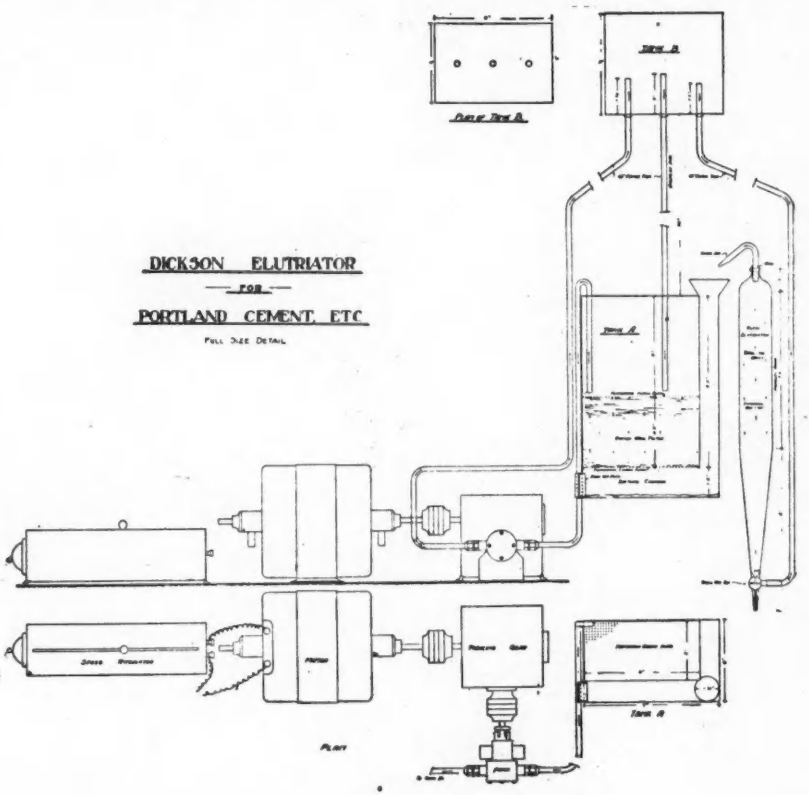


Fig. 2.

selected, but with much greater accuracy and speed and over a range beyond the possibilities of any sieve.

With the instrument shown in the accompanying diagram it is possible to obtain an accurate analysis of the particle size of any cement in a comparatively short time. To separate the coarse particles in Portland cement by means of elutriation it is necessary that the liquid used shall not affect the cement and shall itself be unaffected. The liquid selected is that known in the paint trade as white spirit, or turpentine substitute, and the apparatus consists of an elongated glass separator to which jets of varying size can be fitted. This elutriator is attached to a constant head device, the speed of flow being regulated by a constant head in conjunction with a standard-size jet. The lower conical part of the glass vessel permits of thorough washing of the coarse particles to free them from flour.

To determine the coarse residue in a cement, 10 or 20 grams of the sample are weighed and placed in a 200 c.c. conical beaker; 50 c.c. of white spirit are drawn from the elutriator into the beaker and a small wash-bottle filled from the same source, care being taken to prevent the flow of spirit to the elutriator from the constant head tank. There will now be enough room in the elutriator for the transference from the beaker of the cement by rapid shaking and washing with the wash-bottle. During this process the jet will have been removed, and it is now replaced. The pump having been started, the three-way tap at the bottom of the elutriator is turned so that the liquid flows through the apparatus and out at the jet. The flour will be carried through the jet, leaving the coarse residue behind. At the end of the operation, which is determined by examination of the issuing liquid which must be quite clear, the flow is stopped and the residue, after being allowed to settle, is drawn off, washed with ether, dried gently, ignited, and weighed.

In the following table the amount of coarse residue at three different speeds and the tensile test of each cement are given, and the results suggest that the strength of any given bulk of cement could be forecast from the figures obtained by elutriation.

Sample.	Residue on 180 × 180 Sieve. Per cent.	Per cent. Residue at Speed of Flow. 3 mm. Per Sec.	2 mm. Per Sec.	1 mm. Per Sec.	Tensile Strength 3 : 1 7 days. Lbs. per sq. in.	$\frac{CaO}{SiO_2 + Al_2O_3}$
A	2.3	20.9	28.0	39.25	550	2.77
B	3.4	23.0	30.5	43.75	450	2.62
C	4.7	25.9	35.65	47.85	423	2.59
D	4.8	26.2	35.0	47.65	412	2.59
E	5.5	22.7	30.4	41.37	503	2.61
F	5.8	28.7	38.9	49.7	423	2.65
G	0.4	10.8	18.6	32.7	613	2.85
H	1.1	11.2	19.0	32.0	613	2.73
I	—	11.0	17.8	35.1	687	2.81
K	—	10.0	15.5	32.3	745	2.90

The determination of fineness by the method of sieving may therefore become obsolete and some more useful and accurate method may be adopted as standard, and I hope this short note may be useful in the selection of a more suitable method for the determination of, not fineness, but the amount of coarse particles. My sincere thanks are tendered to Mr. R. H. Harry Stanger for the great help he has given in the experiments and in whose laboratories the work has been carried out.

Notes from Abroad.

Australian Cement Manufacturers' Association.

The " Australian Cement Manufacturers' Association " has been formed for the purpose of advancing the interests of the Portland cement industry in Australia. The President of the Association is Mr. J. Symonds, of the Commonwealth Portland Cement Co., and the Vice-President Mr. D. H. Dureau, of the Australian Cement Co., Ltd. The office of the Association is at 14, Spring Street, Sydney. Mr. R. B. Hinder is the General Manager. All of the cement manufacturers of Australia with the exception of the Swan Cement Co., Perth, are members of the Association.

Proposed Mexican Tariff on Cement.

The Mexican cement manufacturers have filed an application for the imposition of a tariff on imported cement both from U.S.A. and Europe.

New Works in U.S.A.

The Atlas Portland Cement Co. is to build a 1,000,000 barrel plant at Waco, Texas, which will be its sixth plant.

New Capital for Indian Company.

The Shahabad Cement Co., Ltd., is applying to the Hyderabad State for a further debenture loan of 10 lakhs of rupees, for the purpose of doubling its plant. The Hyderabad State are large debenture and shareholders in this company, and advanced Rs. 10,000,000 (£47,682) in 1924. The remaining 5 lakhs of rupees required is to be raised by private subscription.

Belgian Cement Tariff.

It is reported that the Belgian Government has decided to remove all duties on cement in order to allow the industry to compete successfully in overseas markets.

Polish Works to Restart.

Zementfabrik " Wolyn " Zdolbunowo, a plant in Eastern Poland destroyed during the war, is to be restarted. Its pre-war capacity was 120,000 tons per annum.

Raw Materials for Portland Cement Manufacture.

By A. C. DAVIS, M.I.Mech.E., M.Inst.C.E.I., F.C.S.
(Works Managing Director, Associated Portland Cement Manufacturers, Ltd.)

(Continued.)

Proportioning the Raw Materials.

HAVING secured the geological deposits which on analysis give favourable results for the manufacture of Portland cement, the accurate proportioning of these materials has now to be settled.

The exact chemical constitution of Portland cement is not yet known with certainty, but practical experience has shown that ideal cement is generally one in which the lime, silica and alumina are present in such proportions as to form tri-calcium silicate and tri-calcium aluminate. Theoretically, this implies that the magnesia and the iron oxide, always present in cement raw materials, are free and uncombined, but practically, as magnesia is basic and iron oxide acts as an acid radicle, they can be taken to balance each other. In tri-calcium silicate the proportion of lime to silica is 2.8 to 1 by weight, and in tri-calcium aluminate the proportion of lime to alumina is 1.65 by weight. As previously stated, however, these compounds represent the ideal, and in practice the ideal is not attainable, because it is practically impossible to grind the raw materials so finely as to produce a perfect mixture, and therefore the proportions of 2.8 and 1.65 respectively cannot always be adopted in practice. The impossibility of attaining the ideal is indeed recognised by the British Standard Specification, which allows the limit of only 2.9 molecules of lime to silica and alumina. Hence, to determine the proportions of raw material required for cement manufacture, the basis for calculation is that the lime must be 2.7 times the amount of silica, and 1.6 times the amount of alumina. This will give a lime ratio, as calculated by the British Standard Specification methods, of 2.9. But again, even such a standard as this is not always attainable owing to difficulties with raw material grinding, and in commercial cements the lime ratio is usually not more than 2.7.

There is, however, another factor which is introduced and reduces the lime ratio, namely, dilution of the raw materials during the burning process with coal ash, and this dilution is largely responsible for the reduction in the lime ratio. Hence for practical purposes of raw material calculation the factors of 2.7 and 1.6 can be used.

The following is an example of how the calculation is made:—

	Analyses of Clay.	Chalk.
Silica	56.3 ...	0.4
Alumina	21.4 ...	0.2
Ferric oxide	4.5 ...	0.3
Lime	2.4 ...	54.8

Magnesia	1.6 ...	0.7
Loss on ignition	9.4 ...	43.2
Alkalies, &c.	4.4 ...	0.4
	100.0	100.0

Amount of lime to combine with silica :—

Clay silica $\times 2.7 = 56.3 \times 2.7 = 152.01$

Chalk silica $\times 2.7 = 0.4 \times 2.7 = 1.08$

Amount of lime to combine with alumina :—

Clay alumina $\times 1.6 = 21.4 \times 1.6 = 34.24$

Chalk alumina $\times 1.6 = 0.2 \times 1.6 = 0.32$

Total	187.65
Deduct lime in clay ...	2.40
	185.25

Divide by lime in chalk $\frac{185.25}{54.8} = 3.4$.

Mixture should be 3.4 parts chalk to 1 clay.

Slurry composition based on above :—

SiO_2	$0.4 \times 3.4 =$	$1.36 + 56.3 =$	$57.66 \div 4.4 =$	13.1
Al_2O_3 ...	$0.2 \times 3.4 =$	$0.68 + 21.4 =$	$22.08 \div 4.4 =$	5.0
Fe_2O_3 ...	$0.3 \times 3.4 =$	$1.02 + 4.5 =$	$5.52 \div 4.4 =$	1.3
CaO	$54.8 \times 3.4 =$	$186.32 + 2.4 =$	$188.72 \div 4.4 =$	42.9
MgO ...	$0.7 \times 3.4 =$	$2.38 + 1.6 =$	$3.98 \div 4.4 =$	0.9
Loss	$43.2 \times 3.4 =$	$146.88 + 9.4 =$	$156.28 \div 4.4 =$	35.5
Alks. etc. ...	$0.4 \times 3.4 =$	$1.36 + 4.4 =$	$5.76 \div 4.4 =$	1.3
				100.0

ANALYSIS OF RESULTANT CEMENT.

This is obtained by dividing each item in the slurry analysis by 100 – loss on ignition/100 = 0.645, and gives the following result :—

SiO_2	20.3
Al_2O_3	7.8
Fe_2O_3	2.0
CaO	66.5
MgO	1.4
Alkalies, etc.	2.0
	100.0
B.S.S. lime ratio	2.85

In practice the proportions of silica, alumina and iron oxide would be in-

(*Continued on page* 51.)

(*Continued from page* 50.)

creased by contamination with coal ash, while lime would be decreased in proportion and some alkalies would volatilise in the kiln.

Winning and Mixing of Raw Materials.

After choosing the raw materials which when accurately mixed in suitable proportions, will produce a good quality of Portland cement, arrangements must be made for the digging, or quarrying, and mixing and transport of such materials. The methods of winning raw materials are determined by several factors, such as the location of the strata in reference to the natural level of the surrounding country, the hardness of the material, the thickness of the strata, the probable presence of useless overburden, etc. In many cases the strata of the desirable material is waterlogged, and the choice then lies between digging the materials as they lie under water or pumping away the latter.

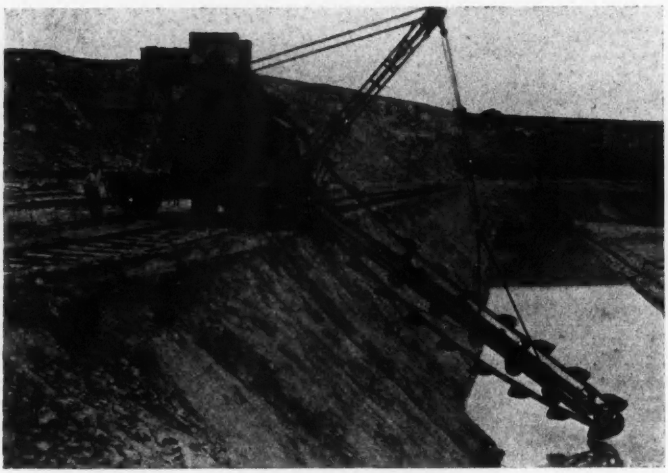
If the cement works are on a small scale it is doubtful in many cases, even with relatively high labour costs, whether the installation of mechanical tools is economical, as the somewhat high capital and maintenance costs are a heavy charge on small outputs. Where, however, weekly quantities of over 1,000 tons are required, suitable mechanical appliances are usually more economical, and in addition to the cheaper cost of operation they enable the work of quarrying to be carried on in wet weather, which could not be done in the case of hand labour only.

Before the introduction of mechanical appliances in the early years of the present century, the softer materials such as chalk, marl, and in many cases clay, were obtained by what is known as " milling," which was carried out by working back the quarry face at a fairly steep slope for a height of 30 to 100 ft. or more, according to circumstances. The bottom of the face is worked to a narrow outlet, at which a truck is placed. The quarrymen stand on small benches which they make in the face of the cliff and, with pointed bars loosen the material which rolls down the sloping face and converges on the narrow outlet and so falls into the truck. This method is one of the most economical ways of digging this class of raw material, as, given suitable conditions, it is possible for a man to dig and put into trucks as much as three tons per hour. The whole of the face cannot, of course, be dug at this speed, as anything below the level of the top of the truck must be dug and lifted into it. This method is used in some small quarries to-day.

The method of digging raw materials generally adopted to-day is the excavator type of machine, which may be electrically driven and fitted with caterpillar travelling gear. Such machines may be obtained to dig very high faces, but generally speaking a machine to operate on a vertical face of about 40 ft. and bucket with a capacity of 3½ yards loose, or a little over three tons actual weight, is most useful. The capacity of such a machine, which is operated by one man, is very large if it is kept in continuous operation, but in average working, owing to shunting of trucks, moving rails as the digging proceeds, etc., the normal rate is considerably below the best possible output While such a machine may maintain a digging rate of, say, 120 tons per hour, it will only be digging for perhaps 50 per cent. and 60 per cent of the time.

With high faces it is necessary to make approach roads at different levels, or to use a second machine working on benchings to dig material and drop it to the bottom level where it can be picked up by the machine working on the bottom level. This involves greater capital expenditure for machines, and also entails handling a proportion of the material twice, but it saves the cost of approach roads, tunnels, etc., and thus there may be little or no difference in the total capital outlay. The machine on the higher levels will not be delayed by tipping into trucks, waiting for shunting, etc.; it can operate at maximum efficiency, and will, generally speaking, dig at double the rate of the one on the bottom level.

Another method of dealing with such a situation is to undercut the face of the material for a considerable length, drill, and put in a charge of blasting



Chain Bucket Excavator.

powder suitable to the material being worked. This will cause the face of the material to collapse, so that one machine at the bottom can then handle it. A similar result may be obtained, perhaps more safely, by drilling vertical holes along a reasonable length of face from the top of the quarry down to the level of the quarry bottom. These holes are located at suitable distances both from one another and from the existing face. They are dug by means of well-drilling equipment, generally driven by electric motor or petrol engine. The holes are charged with powder and the whole simultaneously fired. The capital outlay is here relatively low, but the actual cost of winning the materials is rather higher than benching. Generally speaking, however, the higher the face the more effective is this method.

A machine with many possibilities for soft materials is a continuous-bucket digger, in which open-ended buckets of about 1 cubic foot capacity are mounted

at intervals on a very strong chain. This chain runs over drums at each end of a long lattice-work arm supported by ropes from a powerful carriage running on rails, which houses the driving mechanism, generally electrical, which very slowly moves the whole apparatus along the face of the material. By rotation of the top drum, the chain with the buckets is moved over the face of the material to be dug. The angle of the bucket arm is adjustable so that the slope of the face of the materials may be relatively flat in material which tends to slip. These machines can only deal with soft material, such as a man could dig with a shovel, as the action is that of scraping and the material as dug is actually in the form of laminated pieces about 1 inch thick. Such machines are able to dig at a level either above or below themselves, and may be con-

Excavating by Water Jet.

structed to deal with soft material at the rate of 120 tons per hour from a face 60 ft. above and 60 ft. below the level on which they stand. Thus the total face dealt with from one level may be as much as 120 feet. They are rather more expensive in operation than an electric shovel, and a fair amount of labour is necessary for the frequent lateral shifting of the rails upon which the machines and the truck travel, as they can only operate on a face of about 9 feet without moving, whereas the electric shovel can operate on 40 feet width of face without moving laterally. An important point is that this machine will operate with the bucket ladder immersed in water, and thus can be used on waterlogged strata without pumping. Such machines are also very useful where the level of the top of the deposit is the same as that upon which the works are situated. They operate very well in clay, and particularly if there is sufficient water present to prevent the clay or marl sticking to the buckets; in fact most types of digger operate better with either fairly dry or really wet materials.

Another form of machine which is useful in certain cases is a drag-line excavator. This will, however, only dig moderately soft material from the solid,

but it will cover considerable areas and will dig below its own level. In suitable conditions the cost of operating is approximately the same as for the electric shovel.

In dealing with very soft clays from river beds or marshes an ordinary crane with grab is very suitable. It is relatively cheap in capital and repairs; it is operated by one man, and even quite a small machine will dig up to 80 tons per hour. In cases where the material is actually under water the crane is generally mounted on a floating pontoon, and in some cement works where the wet process is used and the works are adjacent the wash-mill the crane is mounted on the same pontoon and the clay, in the form of slurry, pumped to the shore.

In almost all cases quarries are open-worked and mining is seldom adopted, as it is necessarily much more expensive; but mining is necessary in some cases where the deposit is well below the surface and the strata is of small thickness.

In the case of limestone and hard materials generally the methods mentioned for winning chalk by electric caterpillar shovels and blasting are used. The drilling of shot holes in this case is mostly by means of compressed-air drills.

The transport of the raw material to the works also must depend on topographical conditions. A wire ropeway is most useful and convenient where the level of the ground between the deposit and the works is variable, or where water has to be crossed, and this form of transport has the merit that the material can be delivered over the crushing or grinding machines at any desired level of the ground between the deposit and the works is variable, or where fairly level and there are no very sharp curves, standard-gauge trucks and locos. are the cheapest form of transport as large quantities can be moved by this means, but if the removal of rails is of frequent occurrence this is more cheaply carried out with narrow-gauge rolling stock; much sharper corners can also be negotiated with the narrow (say, 2-ft.) gauge.

In the wet process of manufacture pumping may be usefully adopted in many cases, as has been mentioned for clay slurries. It is, of course, necessary to have cleaning places at the lowest points in the pipe line. A 6-inch diameter pipe-line will, without an unduly high pressure, transport at the rate of about 80 tons per hour of dry material mixed with the requisite water.

Having decided on the methods for winning the raw materials and conveying them to the factory, it remains to amalgamate them efficiently and accurately in certain fixed proportions; either, in the wet process, with the addition of water to the raw materials; or in the dry process by the complete drying, fine grinding, and mixing of the raw materials in their dry state—this depending upon the nature of the materials.

It cannot be too strongly emphasised that the preliminary mechanical blending of the raw materials for the manufacture of Portland cement is a stage requiring the utmost technical skill. The thoroughness of this process primarily determines the quality of the resulting cement, and if the manufacturer is to produce a product of regular and reliable quality the scientific supervision of this branch of the manufacture is of paramount importance.

It is essential that extreme care should be exercised in obtaining the correct proportions of the chalk and clay, or whatever other raw materials may be used in the process, so that the resultant mixture may be relied upon to contain the exact chemical constituents necessary for the manufacture of a thoroughly sound cement; for if the raw materials are not mixed in this proper proportion little or nothing can be done at the later stages of burning and grinding to correct it, and the result will be an inferior product. A very careful check is kept on the relative weights of the raw materials, which are adjusted as necessary to the correct proportions of mixed raw materials, testing for this purpose

Chalk Arriving at Tippler over Washmills.

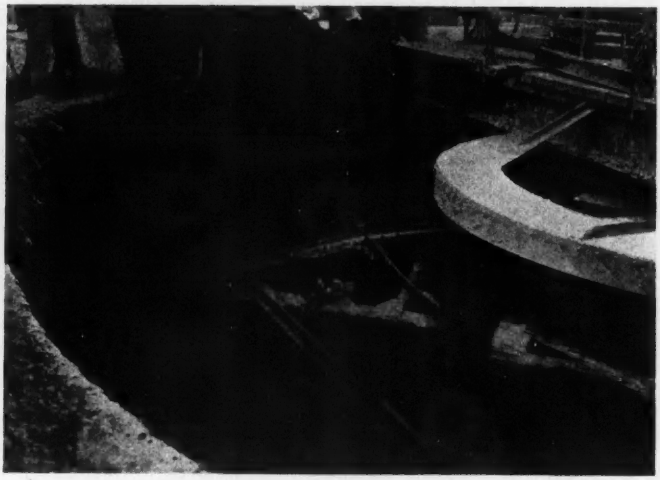
by the works' chemists goes on day and night or so long as manufacture is proceeding. It is obvious that the more regular the composition of the calcareous and argillaceous materials the easier it is to maintain the necessary regularity of the mixture, and pure chalk or limestone and good clay are therefore advantageous.

The hardness of the raw materials is of great importance in determining their commercial value for the manufacture of Portland cement, since the constituents must be ground to great fineness before mixing. Pure hard limestones require pulverising to an impalpable flour, almost all passing a 180² mesh sieve, and are therefore costly to treat; whereas other limestones or chalk-marl containing a considerable proportion of clay are generally much softer, and, the mixing being already done in part by Nature, a better burning combination and finished

cement often result without the high cost of extremely fine grinding and the consequent high capital outlay.

Wet Process.

Of the two principal methods of reducing and mixing raw materials, the "wet process" is applicable mainly, although not solely, to soft materials, which generally contain a fairly high percentage of natural moisture. The correct quantities of the raw ingredients are ground and mixed by the aid of a considerable amount of water, and produce in the final stage a thick creamy liquid containing from 32 per cent. to 42 per cent. of water, the amount of necessary water varying with the nature of the raw materials. This method of mixing, as originated and developed in the United Kingdom, is employed to a considerable extent by the manufacturers of cement on the Thames and



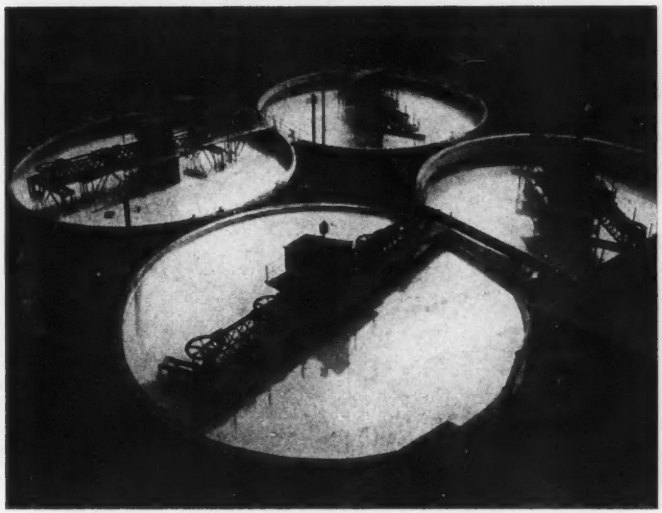
"Roughing" Mill.

Medway. A further reason for the adoption of the wet process in this case is that the chalk in this area contains a large proportion of flint stones which do not break easily and are very easily separated from the chalk at this stage of the process, as the chalk readily mixes with the water and leaves the flints more or less untouched and easily removed.

The soft chalk and clay are weighed into a "roughing washmill," where water is added in considerable quantities. Generally a brick-lined circular pit is used for the washmill, and this is often 24 ft. in diameter by 5 ft. deep. Approximately half the circumference of this basin consists of vertical gratings through which the material under treatment escapes when sufficiently fine to do so. In the centre is a concrete or brick pier, carrying a vertical shaft rotated through a crown-wheel and pinion, and carrying a circular framework from

which are suspended harrows fitted with steel tines. The lumps of chalk and clay suspended in water are broken up by these rotating tines, and the mixture is converted into a thick liquid of creamy consistency which is stirred until fine enough to pass through the gratings. Any flints or stones present in the raw materials remain in the mill and are removed through the bottom from time to time, the frequency depending on the proportion of such stones in the raw materials. The product of the washmill is termed " slurry," or " slip."

The further reduction in fineness of the raw materials, which has been only partially completed in the mill described, is effected in screening washmills similar to the preliminary mill with fine screens, but revolving more rapidly and having much finer screens; the holes in the screens are usually $\frac{1}{2}$ mm. in diameter, while with some harder materials it is necessary for the slurry to be



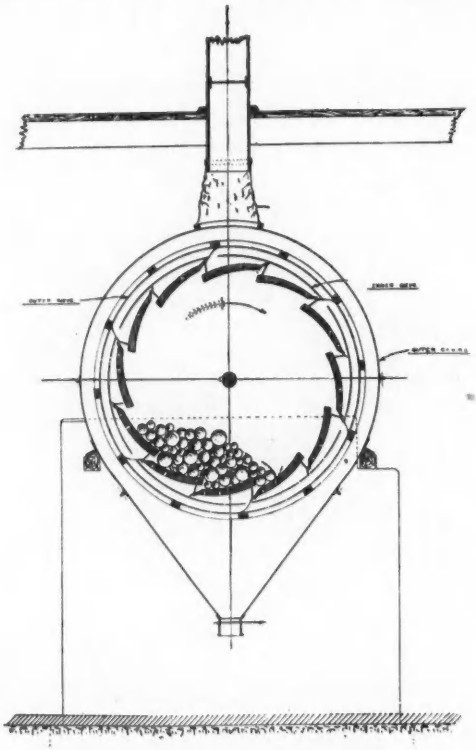
Slurry Mixers.

treated finally in a tubemill (which will be described later) or put through a separating mill.

If the raw materials are very hard the form of mill just described is useless and it is necessary to use crushers, either of the roll or jaw variety depending on the size of the pieces of the raw material as delivered to the mill. These raw materials, reduced to a size of about 2 in. to 3 in. cube, are then fed with the necessary amount of water into a ball mill, which is a horizontal steel cylinder about 8 ft. diameter and about 8 ft. long lined with hard steel plates and shaped so that the internal circumference of the mill is in the form of a series of about twelve steps, each some 6 in. high. Inside the cylinder are about $2\frac{1}{2}$ tons of balls varying in size from 3 in. to 5 in. diameter. The cylinder revolves at a rate of approximately twenty-six revolutions per minute, and the

balls, in cascading over the steps, reduce the raw materials to a size corresponding to that of the first stage of the process.

After this the material goes to the tubemill for final reduction. This mill is also a horizontal cylinder, but the length is much greater than the diameter; a typical mill for this purpose is 6 ft. diameter by 35 ft. long, and requiring approximately 250 H.P. to operate it. In this case the cylinder is lined with



Sectional View of Ball Mill.

plain hard plates, or in some cases hard natural silica blocks set in cement. The interior has no steps as in the case of the ball mill. The grinding media consists here of either ordinary flint pebbles or small hard iron pellets or balls of not more than 1 in. diameter; generally somewhat smaller. The mill has usually about one-quarter to one-third of its internal capacity filled with these bodies. The cylinder revolves at about 22 r.p.m. The partially-finished slurry flows in at one end and out at the other, being reduced to the requisite fineness in its passage.

In some cases ball-mills and tube-mills are now combined in one mill called a " combination " mill. Such a mill has the appearance of a large tube mill,

but is divided vertically into two or three compartments, the first having a charge of balls similar in size to the ball mill, the second smaller balls, and the third, which is the largest, the small balls as mentioned for the tubemill. There is no substantial difference in the power taken or the efficiency of grinding of these mills as compared with the ball and tubemills, but the foundation work is simpler.

The fineness of the raw material at this stage has an important bearing on the subsequent quality of the cement. Generally speaking the nearer the raw material is to the correct composition in its natural state the coarser the grinding can be with satisfactory results. A good average fineness of the finished slurry should have not less than 95 per cent.—better still 97 per cent.—of its solid constituents passing through a sieve with 180 meshes to the square inch.

If the raw materials are hard, relatively dry, and non-absorbent, but of a somewhat variable composition, it is easier to bring them to the correct composition by the wet process than the dry, provided the amount of water is kept so low that the slurry is thick enough to prevent easy settlement of any portion of these materials. This process is called the " thick slurry process " and the moisture in this case may be as low as 30 per cent., although the viscosity and fineness of the slurry may be similar to that of the soft materials with 40 per cent. or more water.

Dry Process.

In the dry mixing of the raw materials the calcareous and argillaceous materials have to be dried, generally by waste kiln-heat, after passing the preliminary crushing machinery. The dryers were originally kilns built of brickwork, but, due to the more general adoption of the dry process of manufacture in countries where hard raw materials are usual, less costly and more efficient methods which can be worked with less labour have been devised. The dryers in modern plants consist of revolving iron cylinders, or drying drums, 50 ft. in length and about 6 ft. in diameter, supported on steel tyres resting on heavy friction rolls, rotating at about two revolutions a minute. They are usually set with an inclination of about $\frac{1}{2}$ in. per foot in the direction of the travel of the raw materials.

The preliminary crusher or rolls reduce the material to $1\frac{1}{2}$ in. to 2 in. cube—the smaller the better; the raw materials are then introduced into the upper end of the dryers, situated immediately behind the exit end, and are caught by cascading channels fitted inside the drums which lift and drop the crushed raw materials as the dryer revolves and present them to the hot gases passing through the drums in the opposite direction to the materials; waste kiln-heat is thus employed for drying purposes. In cases where vertical kilns are employed in place of rotary kilns, as in some works on the Continent, heating furnaces are sometimes provided for the supply of the necessary heat to the dryers. The size of the dryers depends very largely on the nature of the raw materials. In dealing with hard crystalline limestone and non-absorbent shale in a dry country such as Africa the problem is different from the use of a relatively porous limestone and wet land clay in a rainy country. In any case, however,

there is always ample waste heat available to do the work from any dry-process rotary kiln provided a suitable size of dryer drum is provided.

Dry Grinding and Mixing Raw Materials.

The raw materials after crushing and drying have to be reduced to an extremely fine powder or " flour " (approximately of the fineness mentioned as necessary for the wet process) by the same type of plant used for grinding clinker. This is also very similar to that described under " Wet Process " for hard raw materials, but without the introduction of water, as will be explained later. They are then carefully and thoroughly mixed to the proper chemical proportions before being conveyed to the kilns for burning.

Having prepared the raw materials either in the form of a fairly thick slurry or a fine dry powder it is necessary to mix them thoroughly so that they shall be completely homogeneous. The method usually adopted for the wet process is to pump the finished slurry from the mills into deep vertical tanks, holding approximately 100 tons, with a conical bottom and a valve. These are set above the main storage tank and fitted with a series of small inlets at the base for the admission of compressed air. When one of these tanks is full the slurry is diverted into an adjacent one, compressed air automatically admitted, and the whole contents violently agitated. This ensures very thorough mixing in a short space of time—usually about five minutes. The slurry is then discharged into the main storage tanks, which may be open basins of about 70-ft. diameter and 12-ft. deep, holding the equivalent in slurry of some 600 tons of cement and fitted with mechanical agitation, or more frequently to-day a combination of mechanical and low pressure (about 10 lbs. per square inch) compressed air. This keeps the contents gently agitated at a nominal cost and prevents any tendency to settlement of the constituent materials.

In some cases the slurry is stored in vertical silos larger but simpler than those mentioned for mixing. These are fitted with compressed-air inlets and the air admitted at regular intervals. In this case the contents are not discharged into other vessels but remain until required at the kilns. This latter method is as effective as the former but is rather more costly in capital outlay and operation. It has, however, an advantage in very cold countries as the slurry is not so apt to freeze and cause trouble.

Dry raw material is elevated or pumped by means of a special compressed-air and screw-pump to a series of vertical storage tanks similar in many respects to those mentioned for slurry, a useful size for these being about 250 tons of raw material each, equivalent to about 170 tons of cement. Each of these silos is fitted with two or more screw extraction-gears at the bottom and a series of conveyors, generally two under each row of silos. One of these conveyors leads to the main feed to the kilns and the other to the pumps or elevators delivering the ground meal from the mills to the silos. It is then possible to extract the meal from the bottom of one or more of the silos simultaneously into the conveyor leading to the pump and pump it into any other silo, thus circulating the contents of any of the silos until a complete mixture is obtained. It

will be obvious that it is more difficult to obtain a thoroughly homogeneous mixture in this manner as compared with that obtained where the wet process and compressed air is used.

It will also be very easily seen that up to this stage of the manufacture the plant can differ very widely. At the one end of the scale are soft marls of approximately correct composition, easily dug, ground (not necessarily so finely), and mixed in simple mills; at the other end of the scale is hard material requiring extensive drilling and blasting, heavy crushing and milling machinery with dryers to reduce it to a finer state of subdivision, and requiring possibly nearly ten times the power required by the soft marl, with correspondingly higher cost of renewals and repairs of the heavy machinery.

The dry process, as has been explained, is employed where the raw materials cannot be satisfactorily reduced by washmills; it has been used in the Rugby, South Wales, and Cambridge districts but is now being largely superseded by the wet process. America and Canada generally adopt the dry process, as do other countries extensively producing cement from hard non-absorbent materials. The dry method is probably a little cheaper than the wet process on account of the lower fuel consumption in the kilns, but this again depends upon many local factors. Where circumstances allow the use of waste heat boilers for steam raising is adopted.

To sum up, in preparing materials for manufacture of cement, the chalk and clay or other materials of similar composition must first be reduced to a very great degree of fineness by the addition of water or by dry grinding. Both these processes break down the cohesion between the particles and leave the material in a very finely divided state; it is the physical properties of the respective materials to be dealt with which generally determine the method of reduction to be adopted.

Final Composition of Raw Materials.

Before the burning process, which is the next stage in manufacture, the prepared raw material mixture is analysed and tested to ascertain its composition. The variation of carbonate of calcium ($CaCO_3$) should be kept within one-half per cent. of the quantity found to produce the best cement. The percentage may vary slightly according to the geological formations found in different districts, but a combination of 76 per cent. of chalk or similar calcareous material and 24 per cent. of clay or similar material will, generally speaking, produce a good quality cement. Should the proportion of clay be too high (or the percentage of calcium carbonate fall below, say, 75) the mixture will fuse at a temperature lower than that required for the production of sound clinker, thus rendering it comparatively useless for high-class cement. An excess of chalk (above, say, 78 per cent.) will, on the other hand, allow the mixture to sustain the highest temperature in the kiln without fusion, but the clinker would probably be unsatisfactory due to its unsound or expansive tendencies when ground for cement. A variation of only ½ per cent. in the amount of carbonate of calcium will also affect the tensile strength of cement; other things being equal, high lime increases the strength and low lime reduces strength.

Analysis of Mixed Raw Materials.

The chemically mixed raw material prepared in the ordinary course of manufacture may, therefore, analyse as follows:—

Silica	16.0 per cent.	Clay.
Alumina and oxide of iron	6.5 ,, ,,	
Undetermined	0.5 ,, ,,	
Carbonate of calcium	76.5 ,, ,,	Chalk.
Carbonate of magnesia	.5 ,, ,,	

Such a material, if properly treated in the further stages of manufacture, will produce a good commercial cement.

(To be continued.)

The Future of Cement Testing.

FOLLOWING the paper read by Mr. D. B. Butler, A.M.Inst.C.E., F.C.S., on "Recent Improvements in Cement Manufacture," at the Institution of Structural Engineers (reported in our December, 1928, number), an interesting discussion took place, of which the following is an abstract:—

Mr. R. H. Harry Stanger said he was in absolute agreement with Mr. Butler's suggestion that the 28-day test should be dispensed with. It was very rarely that cements were tested for 28 days because it meant delay and the locking up of too much capital. As a rule a 3-day test was substituted. He very frequently accepted cements after they had been subjected to 3-day and 7-day tests. There were several specifications in use for rapid-hardening Portland cements. A specification to which he worked regularly provided for a strength of 300 lbs. per square inch after 1 day and 550 lbs. per square inch after 7 days. Mr. Butler had recommended a strength of 600 lbs. per square inch after 7 days, and no doubt that could be obtained, but the testing houses must exercise care in the way in which they cured the briquettes.

He agreed that it was time we dispensed with the neat tensile tests entirely. The compression test, on the other hand, was important, and he had spoken in favour of it at the meetings of the B.E.S.A. Committee, but he had always been told that the testing of cement already cost as much as it should, and if more tests were applied to it the cost would increase.

He did not agree with Mr. Butler's remarks on primary set; he did not think that primary set, or false set, had any effect on the strength of the cement. He had carried out experiments recently on a cement which exhibited this false set. With two minutes' gauging it set in ten minutes, but with five minutes' gauging the set was normal, i.e. about 100 minutes. He had gauged it for two minutes and then let it set; then it was taken out of the mould and re-gauged and made into a briquette and was tested against a briquette which had been gauged for five minutes, and both of them had broken at the same load. He believed the

false set was due to the great heat developed in the tube mill when grinding clinker, and he believed endeavours were being made to reduce that heat.

Mr. Henry Pooley said it was difficult to secure agreement even between expert cement testers in regard to given batches of cement. Some of the provisions of the British Standard Specification were rather lax, as indicated by the absence of a sharp line of demarcation between hammering and the operation which an operator might term rather heavy tapping. It would be advantageous to introduce an automatic hammering machine such as was used on the Continent; with such a machine we should be more likely to obtain more uniform results, and should certainly be able to compare cements more easily.

Mr. W. H. Woodcock (Messrs. Woodcock & Mellersh) said he differed from Mr. Butler, and agreed with Mr. Stanger, with regard to the primary and secondary initial setting time. The false, or primary, set was due very largely to the partial dehydration of the gypsum used and its subsequent partial setting. It was particularly noticeable in heavily gypsumised cement which had been very finely ground and presumably heated. He had found, as had Mr. Stanger, that after extended gauging the setting time was normal. When the real initial set was destroyed the later setting was very indefinite, sometimes extending over a period of some days, and the cement was much weaker; on the other hand, the false initial set could be destroyed without rendering the cement unsatisfactory.

Mr. F. S. Giller said that his experience in supervising the building of factories in many different countries had emphasised how very difficult it was to arrive at a specification. The very rapidity with which improvements in the quality of cement had been and was being effected made it very dangerous to arrive at a standard specification at the present time.

Sir Henry Tanner, C.B., I.S.O., in a written contribution, said the author of the paper had traced the very great improvement in the quality of cement and its development in the direction of slow setting and quick hardening which had taken place since the establishment of the British Standard Specification, dated about 1904. Mr. Deane, in a paper at the Royal Sanitary Institute Congress, in July, said that although the strength of cement had increased some 300 per cent. the same mixes were being used as was the case 25 years ago, whereas economies in the quality of cement used should be effected. His object in writing was to draw attention to the Regulations, dated 1878, now in force under the London Building Acts. These required a cement mortar of 1 to 4 of sand, the same as was required at its first appearance in Regulations, and a concrete of 1 to 8 of aggregate, and for reinforced concrete of 1 : 6. In the face of these Regulations how were economies to be effected, especially as the dimensions of brickwork were laid down and no allowance made for the improvement in the mortar? In these circumstances, it would be a great help if experts could indicate how economies could be devised and so lower the costs of building which at the present time were so excessive.

Mr. H. Jackson, in a written contribution, said there seemed to be a large amount of agreement amongst cement testers that the neat tensile tests were not a reliable guide to the serviceable qualities of the cement. The exceeding

fineness of modern cement had made it very sensitive to the conditions of " making up " and to atmospheric conditions. If one might use as an illustration the micro structure of steel, the crystals in setting from the matrix (the mother liquid in the case of steel—the cement " gell " in the case of cement) formed themselves irregularly, and the " space lattices " of the crystals being uneven, there was no concerted action through the whole mass. This was overcome in the case of steel by annealing and normalising. With cement this could not be done, and the existence of the very properties most desired in the cement made the neat cement tensile test unreliable as an indication of what kind of concrete the cement would make. Might it not be better to do away with the neat cement test altogether?

The author, in a written reply to the discussion, said Mr. H. Jackson had suggested the abolition of the neat test, and this point was also discussed by Mr. Stanger, Mr. J. G. Kay and Mr. H. G. Lloyd. The first two speakers supported Mr. Jackson's view, but Mr. Lloyd pointed out that the tester was required to test the cement and not a mortar, and it seemed reasonable therefore to apply the test to the cement alone. Personally the author would be very sorry to see the neat test abolished altogether, since it sometimes gave valuable information as to the hardness and cohesive value of the cement as apart from its adhesive value. This particularly applied to some varieties of cement other than true Portland cement, which, although they gave a highly satisfactory sand tensile test, were distinctly on the soft side when gauged neat, and gave a very poor neat test in comparison. He was pleased to find from the remarks of Mr. Stanger and other speakers that his (the author's) suggestion for the substitution of a 3-day test for the present 28-day test appeared to be favourably received. Major R. R. Woodcock and other speakers supported the desirability of the adoption of compression tests, in addition to, or in substitution for, the present tensile tests. While fully admitting that concrete in actual use was more usually subjected to compressive stress than to tensile stress, the author maintained that tensile tests indicated the strength and quality of cement quite as well as compression tests, and since the former were simpler and more easy of application he saw no adequate reason for the change. One thing, however, was certain, that if compression tests were adopted it would cut out all but works tests and professional tests since the cost of the necessary machines and plant would render any testing by the user more or less out of the question.

Trade Notices.

British Industries Fair.—Messrs. Davidson & Co., Ltd., of Belfast, are showing a range of " Sirocco " fans for ventilation, dust removal, etc., at the British Industries Fair, Birmingham, 1929. A method of grit collection is exemplified by the Davidson patent flue-dust collector, of which a working model is shown. A similar collector for dealing with industrial dust may also be seen at work.